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PENSOFT

Pleurocarpous and cladocarpous mosses (Bryophyta) of Parque Nacional da Chapada das Mesas, with newly recorded species from Maranhão and the northeast region of Brazil

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Abstract

Located in southwestern Maranhão, the Parque Nacional da Chapada das Mesas (PNCM), with an extent of about 160,046 ha, is completely inserted in the Cerrado phytogeographic domain. The topography is characterized by a plateau formation consisting of steep hills and medium-altitude mountains with flat tops, which give the PNCM its name. We present an annotated checklist of the mosses that occur in the PNCM. Our checklist includes 26 species of pleurocarpous mosses distributed in 10 families and 22 genera and two species of cladocarpous mosses of the family Orthotrichaceae. The most species-rich families of pleurocarpous mosses were Sematophyllaceae (7 spp.), Pylaisiadelphaceae (6 spp.), and Stereophyllaceae (4 spp.). Eleven species are recorded for the first time from Maranhão and three species are recorded for the first time in the northeast region of Brazil. *Taxithelium pluripunctatum* (Renauld & Cardot) W.R. Buck and *Trichosteleum glaziovii* (Hampe) W.R. Buck, are recorded for the first time from Maranhão and the Cerrado phytogeographic domain. Our results expand the knowledge of the Brazilian bryoflora and add distribution data for a number of species in Maranhão and the northeast region.

Keywords

Bryophytes, Cerrado, floristic survey

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Introduction

Pleurocarpous mosses differ from other mosses by having their sporophytes produced laterally on the main branch and branches. On the other hand, in cladocarpous mosses sporophytes are solely produced at the apex of the branches (LaFarge-England 1996).

Pleurocarpous and cladocarpous mosses of Brazil have mainly been studied in the Northeast Region. For example, in a study of the cladocarpous mosses of the Michelin Ecological Reserve (Igrapiúna, Bahia), Bastos and Vilas Bôas-Bastos (2008) recorded three genera

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and four species, all belonging to Ortotrichaceae Arn. In another study, on pleurocarpous mosses of Sete Passagens State Park (Bahia), which focused on microenvironments, colonized substrates, and geographic distribution patterns in patches of rock outcrops and deciduous forest, Ballejos and Bastos (2009) recorded 31 species distributed in 13 families and 23 genera, among which were species recorded for the first time from the Bahia and the Brazilian Northeast Region. And, from within remnants of ombrophilous forest in the Atlantic Forest, Vilas Bôas-Bastos and Bastos (2009) recorded 37 species of pleurocarpous mosses belonging to 10 families and 24 genera (77% of the total species number). Most of the taxa that they reported were members of Hypnales (Bryophyta, Bryopsida), and furthermore, 15 species were recorded for the first time from Bahia, four of which were also previously unrecorded from the Northeast Region. In study on pleurocarpous mosses in an Atlantic Forest remnant with waterfalls in Chapada da Ibiapaba (Ceará), Oliveira and Bastos (2010) recorded 24 species in nine families and 17 genera; nine of the species were recorded for the first time from Ceará, six from the Northeast Region, and one from Brazil. Most recently, Evangelista et al. (2019) recorded 56 species of pleurocarpous mosses, distributed in 16 families, at Estação Ecológica Wenceslau Guimarães (Bahia), which protects an important remnant of ombrophilous forest with patches of nebular forest.

Most of these previous studies in the Northwest Region were performed in the Atlantic Forest phytogeographic domain, and this suggests the need for more studies of the bryoflora in other domains in the region. Few studies were made of the bryoflora of the Cerrado, even though this domain is diverse, with 478 species, including 38 that are endemic (Costa and Peralta 2015). Only one study on the pleurocarpous mosses in Maranhão has been published (Conceição et al. 2010), which recorded 11 species in the municipality of Caxias. Thus, the need of more knowledge was our motivation to do our survey.

The amount of research is even less if one considers studies on bryophytes in protected areas. Protected areas are responsible for protecting natural resources in Brazil (MMA 2019) and have a fundamental importance in maintaining biodiversity, including the bryoflora, whose species are extremely sensitive to environmental changes (Halliback and Hodgetts 2000). However, of the 43 protected areas currently in Maranhão (MMA 2019), only 12.5% of area is Cerrado, and of these only 5.7% has full protection (Spinelli-Araújo et al. 2016).

Recently, Ferraz et al. (2020) studied the floristic composition of savanna and forest Cerrado physiognomies in the Parque Nacional Chapada das Mesas (PNCM), the floristic relationships with other Brazilian Cerrado areas, and the floristic relationships between the Cerrado and the Amazon and the Caatinga and Atlantic Forest phytogeographic domains. A total of 242 species in 181 genera and 64 families were recorded; 50 species were reported for the first time from Maranhão, four for the first time from the Cerrado, and one vulnerable species was included. Oliveira et al. (2018) also conducted research on the bryoflora of the PNCM, but focussed on acrocarpous mosses.

There is still a knowledge gap for bryophytes in the PNCM, and our study aims is to provide a species list of pleurocarpous and cladocarpous mosses of the PNCM.

Methods

Study area. PNCM, in southwestern Maranhão, is characterized by numerous sandstone plateaus, with flat tops similar to tables that give the park its name (mesa = table in Portuguese). The park's altitude ranges from 250 m a.s.l. in valleys to 524 m a.sl. on its plateaus. The park spans the municipalities of Carolina, Estreito, and Riachão (Marques and Amorim 2014) (Fig. 1).

The PNCM is an integral protected area where scientific research, environmental education, and ecological tourism activities are developed. It has as its main goal the preservation of natural ecosystems of great ecological relevance and scenic beauty, and it is an area of Cerrado, which is threatened by the recent expansion of the agricultural frontier in southern Maranhão. The climate is humid tropical, according to the Köppen classification, with an average annual temperature of 26 °C and a maximum of 36 °C. Summers (May to October) are dry and winters (November to April) are rainy (Marques and Amorim 2014).

The vegetation of the PNCM is typical of the Cerrado domain, characterized by a mosaic of savanna and forest formations, where species native to the Caatinga and the Amazon domains are also found (MMA 2007). White-sand formations are predominant in the PNCM and are either called cerrado sensu stricto, when the vegetation is taller and composed of treelets and bushes, or campo sujo, when the vegetation is savanna-like. Well-preserved gallery forests grow along watercourses, and patches of semi-deciduous forests occur in areas with richer soils, mainly on mountaintops (MMA 2007).

According to MMA (2007), the PNCM is a high-priority area for the conservation of the Cerrado domain, which is one of the 25 global hotspots (Myers et al. 2000). The park forms part of the Araguaia-Bananal ecological corridor (Marques and Amorim 2014).) This region of the PNCM has a significant value for the maintenance of Brazilian biodiversity, as it is an ecotone between the Cerrado, Amazon, and Caatinga phytogeographic domains. The PNCM has great potential to harbor a species-rich flora.

Sampling and data treatment. Three field expeditions lasting three to five days each were made between April 2016 and July 2017. The collections were made during free walks around the banks of waterfalls and in the vegetation around them. This method allowed us to collect on all types of environments: banks of the waterfalls, shaded and dry environments, rocks, soil, bark, litter, and other habitats that bryophytes colonize.

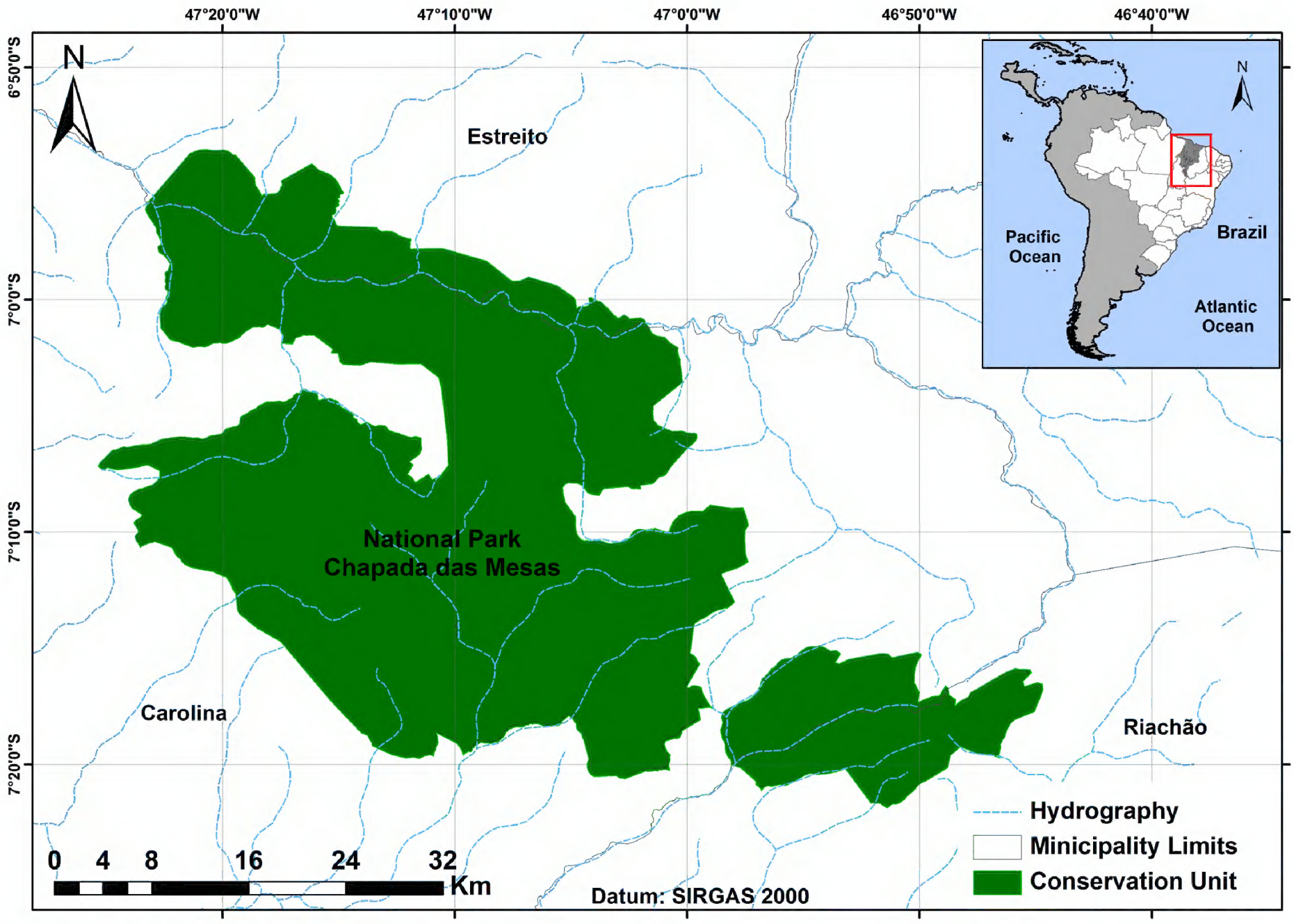

Figure 1. Location of the Parque Nacional da Chapada das Mesas.

The methods for collecting, drying, and preserving the material followed Gradstein et al. (2001). The collected samples were deposited in the Herbarium "Professor Aluízio Bittencourt" (HABIT) at the Universidade Estadual do Maranhão, with duplicates in the Herbarium "Maria Eneyda P.K. Fidalgo" (SP).

Specialized literature was used for identifing species, including Sharp et al. (1994), Buck (1998), Gradstein et al. (2001), Câmara (2008), and Yano and Peralta (2009, 2011).

The classification system adopted for Bryophyta follows Goffinet et al. (2009). Species are arranged alphabetically by family, genus, and species. The distributions of species in Brazil are presented following the methods of Valente and Pôrto (2006), which considers species: (1) "rarely distributed", if they occur in one to four states; (2) "moderately distributed", when occurring in five to nine states; and (3) "widely distributed", when species occurring in 10 or more states. Geographical distributions follow Forzza et al. (2010), Costa et al. (2011), and Costa and Peralta (2015). Information on the type of substrate colonized is recorded following the classification of Robbins (1952): bark (corticicolous), litter (epixilous), leaf (epiphyllous), rock (rupicolous), and soil (terricolous).

The species list includes brief characterizations and figures of the species found for the first time from the Northeast Region, Maranhão, or the Cerrado domain; for other species we cite illustrations in the literature. Species that are recorded for the first time from Maranhão are marked by an asterisk (*), and two asterisks (**) to new records for Northeast.

The collection license (no. 50981) was proviced by Instituto Chico Mendes de Conservação da Biodiversidade in accordance with Brazilian legislation.

Results

In the PNCM we found 28 species, including 26 species of pleurocarpous mosses distributed in 10 families and 21 genera and two genera and species of cladocarpous mosses represented solely by the family Orthotrichaceae. Eleven species are recorded for the first time from Maranhão. *Herpetineuron toccoae* (Sull. & Lesq.) Cardot., *Entodon hampeanus* Müll. Hal., and *Trachyphyllum dusenii* (Müll. Hal. ex Broth.) Broth. are recorded for the first time from the northwest region. *Taxithelium pluripunctatum* (Renauld & Cardot) W.R. Buck and *Trichosteleum glaziovii* (Hampe) W.R. Buck are recorded for the first time from Maranhão and to the Cerrado. The most species-rich families of pleurocarpous mosses in the PNCM were Sematophyllaceae Broth. (7 spp.), Pylaisiadelphaceae Goffinet & W. R. Buck (6 spp.) Stereophyllaceae W. R. Buck & Ireland (4 spp.), Pterobryaceae Kindb. (2 spp.), Hypnaceae Schimp. (2 spp.), and Anomodontaceae Kindb., Entodontaceae Kindb., Pilotrichaceae Kindb., and Pterigynandraceae Schimp. (each with 1 sp.) (Fig. 2). The aforementioned families account for 40% of the PNCM's bryoflora.

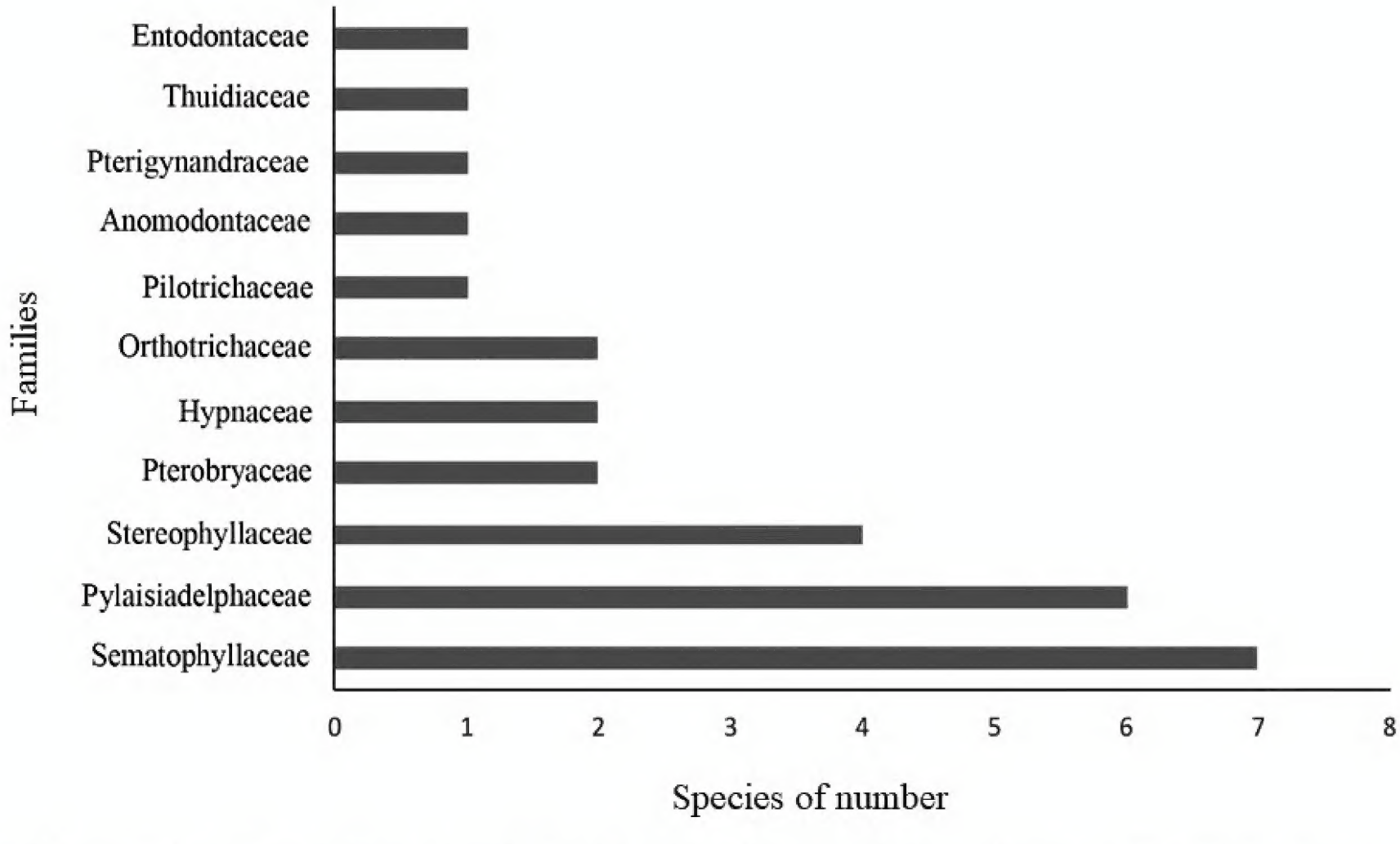

Figure 2. Species richness of the cladocarpous and pleurocarpous moss families at the Parque Nacional da Chapada das Mesas.

Anomodontaceae Kindb.

***Herpetineuron toccoae* (Sull. & Lesq.) Cardot.**
Figure 3I, J

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2534 • 1 specimen; Prata waterfall; 06°59′06″S, 047°09′95″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2524.

This species is reported from the Brazilian Northeast Region for the first time.

Identification. Plants robust, terete-foliate when dry, forming thick, dense mats, stems creeping-prostrate, leaves involute when dry, ovate-lanceolate, apex acute to acuminate, costae single, long, almost reaching the apex.

Geographic distribution. Moderately distributed: MT, MG, RJ, SP, PR, RS, SC.

Entodontaceae Kindb.

***Entodon hampeanus* Müll.Hal.**
Figure 3D–F

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Mansinha RPPN; 07°07′85″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3153.

This species is reported from the Brazilian Northeast Region for the first time.

Identification. Plants with creeping, often irregularly branched stems, leaves linear to oblong-linear, smooth, concave with a weak, double, short costa, alar region well differentiated.

Geographic distribution. Moderately distributed: DF, GO, MT, MG, RJ, SP, RS.

Hypnaceae Schimp.

***Chryso-hypnum diminutivum* (Hampe) W.R. Buck**

Figured by Sharp et al. 1994; Churchill and Linares 1995; Florschütz-De Waard and Veling 1996; Duarte-Bello 1997; Buck 1998; Yano and Peralta 2007.

Material examined. BRAZIL • 21 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 2530, 2531, 2538, 2541, 2554, 2558, 2562, 2568, 2569, 2570, 2572, 2589, 2590, 2593, 2614, 2620, 2628, 2635, 3123, 3127, 3410 • 62 specimens; same locality; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2655, 2659, 2674, 2675, 2677, 2678, 2679, 2680, 2681, 2682, 2901, 2907, 2910, 2929, 2930, 2937, 2938, 2941, 2942, 2943, 2948, 2951, 2960, 2967, 2969, 2974, 2976, 2977, 2980, 2981, 2983, 2987, 2993, 3000, 3001, 3003, 3005, 3006, 3007, 3010, 3216, 3222, 3233, 3238, 3239, 3241, 3305, 3307, 3308, 3311, 3314, 3321, 3322, 3324, 3326, 3327, 3328, 3333, 3336, 3338, 3339, 3341 • 1 specimen; Encanto azul waterfall; 07°13′27″S, 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2770 • 9 specimens; Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3170, 3172, 3176, 3181, 3183, 3191, 3201, 3205, 3212 • 1 specimen; Canto da Rosa; 07°08′07″ S, 047°04′05″ W; 11 Jul. 2016; F.B. Costa leg. HABIT 3289 • 1 specimen; Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; G.M. Conceição leg.; HABIT 3094.

Geographic distribution: Widely distributed: AC, AM, AP, DF, ES, GO, MG, MT, PA, PE, PR, RJ, RR, RS, SC, SP.

***Vesicularia vesicularis* (Schwägr.) Broth.**

Figured by Sharp et al. 1994; Churchill and Linares 1995; Florschütz-De Waard and Veling (1996);

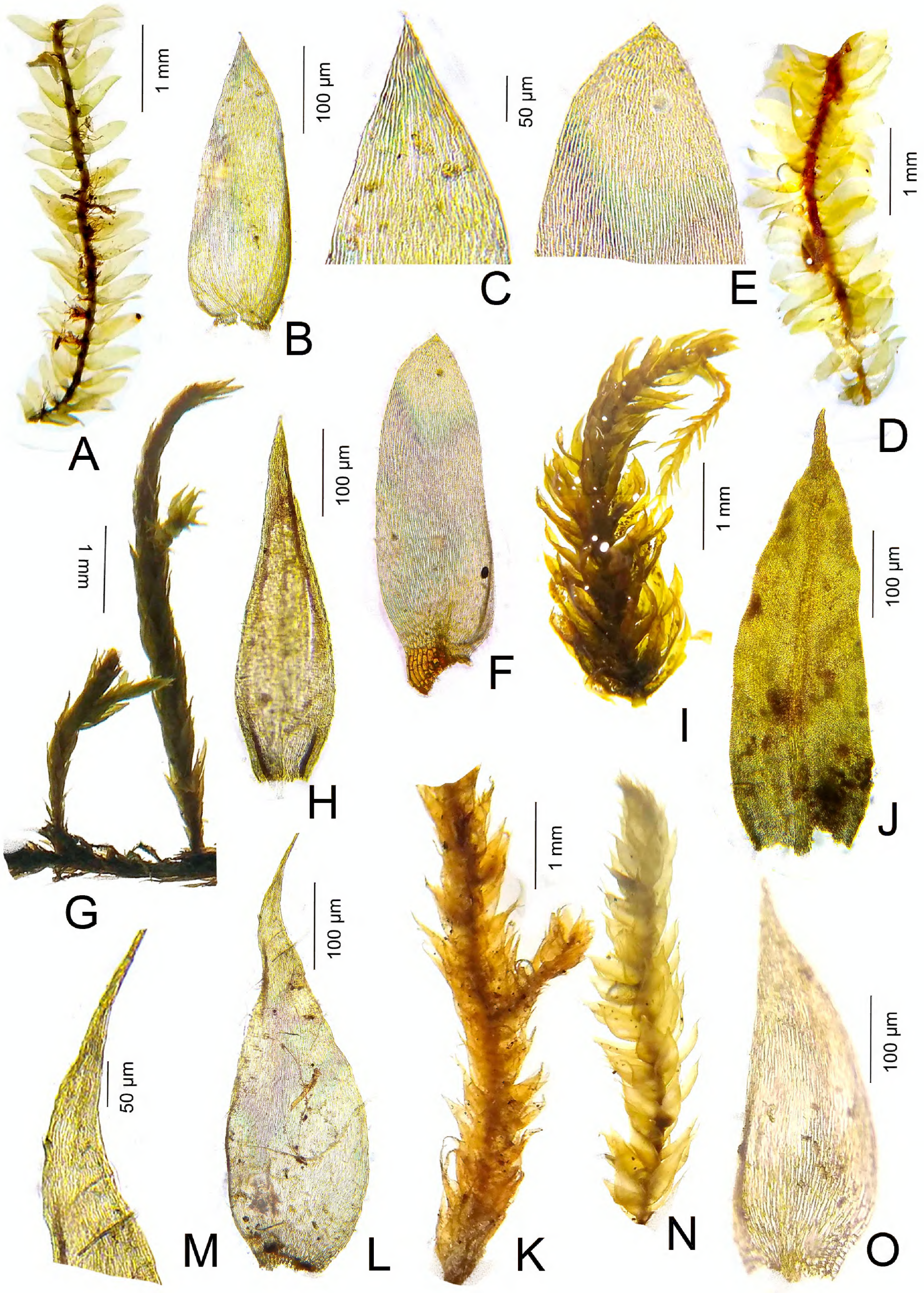

Figure 3. *Donnellia commutata*. **A.** Gametophyte. **B.** Leaf. **C.** Detail of the leaf apex. *Entodon hampeanus*. **D.** Gametophyte. **E.** Leaf. **F.** Detail of the leaf apex. *Henicodium geniculatum*. **G.** Gametophyte. **H.** leaf. *Herpetineuron toccoae*. **I.** Gametophyte. **J.** Leaf. *Isopterygium affusum*. **K.** Gametophyte. **L.** leaf. M. Detail of the leaf apex. *Isopterygium subbrevisetum*. **N.** Gametophyte. **O.** Leaf.

Duarte-Bello (1997); Buck (1998); Yano and Peralta (2007).

Material examined. BRAZIL • 38 specimens; Maranhão, Carolina, Chapada das Mesas National Park, São Romão waterfall; 07°01′28″S; 047°02′45″W; 13 Jul. 2016; R.R. Oliveira leg. (HABIT 2525, 2527, 2528, 2532, 2533, 2535, 2540, 2545, 2548, 2555, 2559, 2564, 2574, 2585, 2586, 2587, 2591, 2592, 2594, 2595, 2596, 2597, 2599, 2602, 2603, 2604, 2605, 2610, 2612, 2613, 2624, 2636, 2637, 2639, 3113, 3126, 3138, 3403) • 10 specimens; Encanto azul waterfall; 07°13′27″S; 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2689, 2702, 2704, 2710, 2715, 2721, 2745, 2757, 2761, 2769 • 4 specimens; Serrinha waterfall; 06°58′07″S, 047°22′42″W; 11 Jul. 2016; G.M. Conceição leg.; HABIT 2819, 2828, 2858, 2864 • 6 specimens; near Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; F.B. Costa leg.; HABIT 3016, 3020, 3030, 3045, 3255, 3414 • 12 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2903, 2944, 2953, 3016, 3020, 3030, 3045, 3213, 3224, 3255, 3337, 3414.

Geographic distribution. Widely distributed: AC, AM, AP, PA, RO, RR, TO, BA, PE, PI, ES, MG, RJ, SP, PR, RS, SC.

Orthotrichaceae Arn.

***Groutiella tomentosa* (Hornsch.) Wijk & Margad.**

Figured by Vitt and Crum 1970; Crum and Anderson 1981; Sharp et al. 1994; Churchill and Linares 1995.

Material examined. BRAZIL • 2 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3179.

Geographic distribution. Widely distributed: AM, PA, RO, AL, BA, PE, SE, MT, RJ, SP, RS.

***Macromitrium swainsonii* (Hook.) Brid.**

Figured by Sharp et al. 1994, as *Macromitrium altituberculosum*; Yano and Peralta 2007, as *Macromitrium altituberculosum*.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Prata waterfall; 06°59′06″S, 047°09′09″W; 13 Jul. 2016; G.M. Conceição leg.; HABIT 2642.

Geographic distribution. Moderately distributed: RO, RR, TO, MA, GO, MT, MS.

Pterobryaceae Kindb.

****Henicodium geniculatum* (Mitt.) W.R. Buck.**

Figure 3G, H

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2560 • 10 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2650, 2657, 2661, 2669, 2670, 2676, 2985, 2994, 2999, 3320.

This species is reported from Maranhão for the first time.

Identification. Recognized by revolute margins, alar region with numerous quadratic cells, cells uni- to pluripapillose, costae subpercurrent ½–¾ of the leaf length.

Geographic distribution. Widely distributed: AC, AM, AP, PA, RO, AL, BA, CE, PB, PE, DF, GO, MT, ES, MG, RJ, SP.

****Jaegerina scariosa* (Lorentz) Arzeni**

Figure 4A, B

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Serrinha Waterfall; 06°58′07″S, 047°22′42″W; 20 Apr. 2016; G.M. Conceição leg.; HABIT 1638 • 2 specimens; Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3189, 2835.

This species is reported from Maranhão for the first time.

Identification. Characterized by simple secondary stems, densely foliated, leaves patent when dry or fresh, but never recurved, broadly ovate.

Geographic distribution. Widely distributed: AC, AM, PA, RO, RR, TO, AL, BA, CE, PE, DF, GO, MS, MT, ES, MG, RJ, SP, SC.

Pterigynandraceae Schimp.

*****Trachyphyllum dusenii* (Müll. Hal. ex Broth.) Broth.**

Figure 4G, H

Material examined. BRAZIL • 4 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Encanto azul waterfall; 07°13′27S, 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2719, 2735, 2737, 2950 • 6 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 3330, 2726, 2936, 2949, 2950, 3009.

This species is reported from the Brazilian Northeast Region for the first time.

Identification. This species is restricted to the Cerrado domain. Plants forming opaque yellowish-green to golden mats, leaves ovate-lanceolate to broadly lanceolate, flat to slightly concave, teeth weakly crenulate, apex acute, apical and medial cells linear, with prominent papillae in each extremity, sometimes smooth at apex, alar region differentiated, cells quadratic to rectangular, double costate, ⅓–¼ of the leaf length.

Geographic distribution. Rarely distributed: DF, GO, MT, MG.

Pilotrichaceae Kindb.

***Callicostella pallida* (Hornsch.) Ångström**

Figured by Sharp et al. 1994; Churchill and Linares 1995; Duarte-Bello 1997; Buck 1998a; Yano and Peralta 2007.

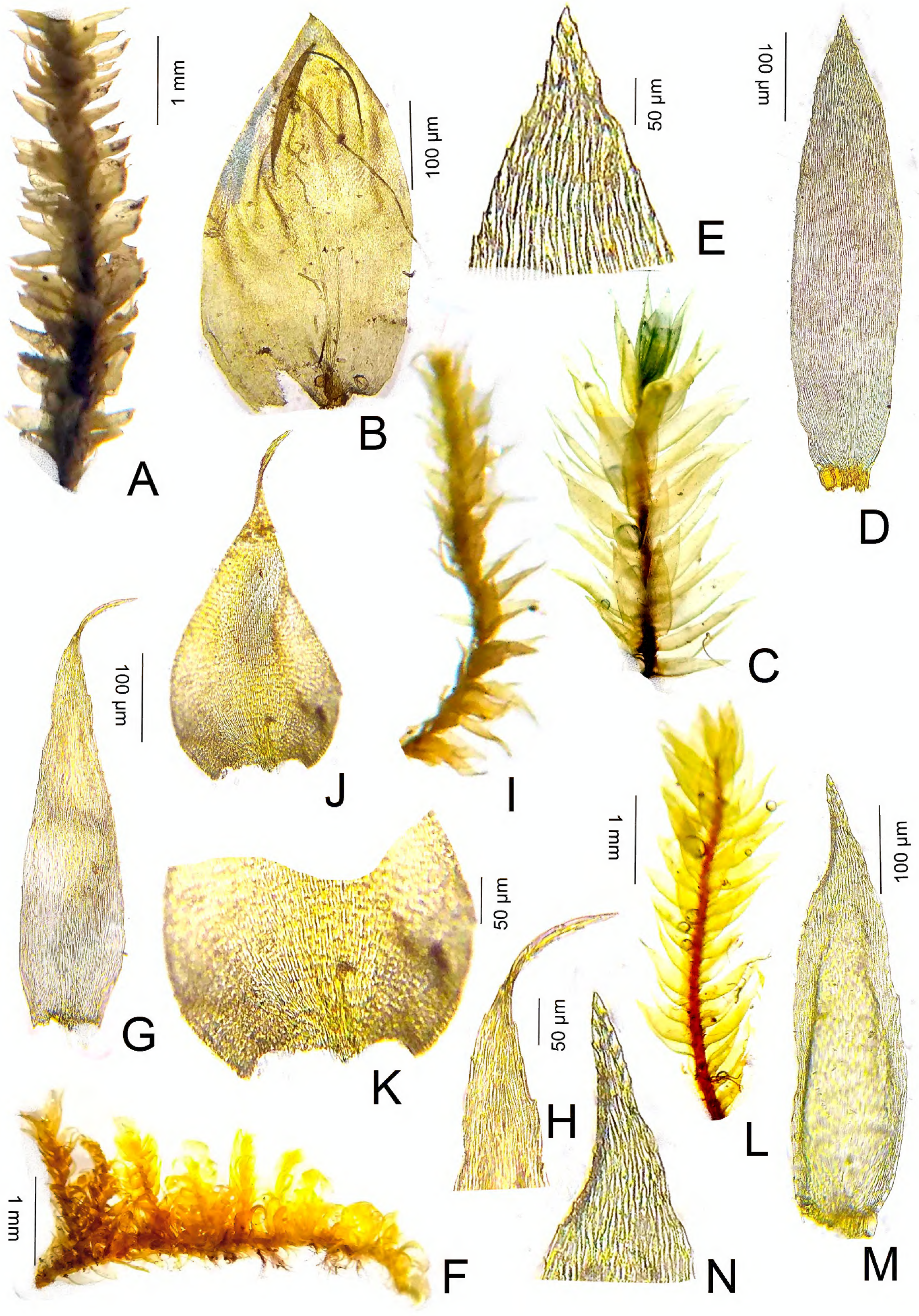

Figure 4. *Jaegerina scariosa*. **A.** Gametophyte. **B.** Leaf. *Potamium lonchophyllum*. **C.** Gametophyte. **D.** Leaf. **E.** Detail of the leaf apex. *Trachyphyllum dusenii*. **F.** Gametophyte. **G.** Leaf. **H.** Detail of leaf base. *Taxithelum pluripuncatatum*. **I.** Gametophyte. **J.** Leaf. **K.** detail of the leaf apex. *Trichosteleum glaziou*. **L.** Gametophyte. **M.** Leaf. **N.** Detail of the leaf apex.

Material examined. BRAZIL • 11 specimens; Encanto azul waterfall; 07°13′27″S, 46°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2683, 2693, 2694, 2703, 2708, 2716, 2717, 2741, 2742, 2744, 2746 • 7 specimens; Serrinha waterfall; 06°58′07″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2792, 2794, 2833, 2836, 2839, 2851, 2857 • 1 specimen; Dantas river; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2892 • 1 specimen; Mansinha RPPN; 07°07′08″S, 047°25′94″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3174 • 5 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2940, 2979, 2986, 3310, 3313.

Geographic distribution. Widely distributed: AC, AM, AP, PA, RO, RR, AL, BA, CE, PE, RN, SE, DF, GO, MS, ES, MG, RJ, SP, PR, RS, SC.

PYLAISIADELPHACEAE Goffinet & W.R. Buck

***Isopterygium affusum* Mitt.**

Figure 3K–M

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Riacho Dantas; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; F.B. Costa leg.; HABIT 2883 • 3 specimens; Canto da Rosa; 07°08′07″S, 047°04′05″W; 11 Jul. 2016; F.B. Costa leg.; HABIT 3294, 3297, 3140 • 2 specimens; Encanto azul waterfall; 07°13′27″S, 046°27′10″W; 20 Apr. 2016; R.R Oliveira leg.; HABIT 2740, 2896 • 2 specimens; Mansinha RPPN; 07°07′85″S, 047°25′94″W; 13 Jul. 2016; G.M. Conceição leg.; HABIT 3194, 3300.

This species is reported from Maranhão for the first time.

Identification. Plants yellowish or green, stems creeping, simple or sparingly and irregularly branched, leaves erect-spreading to squarrose, lanceolate, apex acuminate, alar region poorly differentiated, laminal cells smooth, ecostate.

Geographic distribution. Widely distributed: AM, PA, CE, GO, MT, MG, RJ, SP, SC.

***Isopterygium subbrevisetum* (Hampe) Broth.**

Figure 3, N–O

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, near to Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; G.M. Conceição leg.; HABIT 3037.

This species is reported from Maranhão for the first time.

Identification. Plants in thin to dense mats, recognized by the leaves sub-erect and distant or loosely arranged in the stem, costae generally absent and alar region with 1–3 alar cells little differentiated.

Geographic distribution. Widely distributed: AC, AM, AP, PA, RO, RR, BA, CE, PR, SC.

***Isopterygium tenerum* (Sw.) Mitt.**

Figured by Ireland 1992; Sharp et al. 1994; Churchill and Linares 1995; Florschütz-De Waard and Veling 1996; Duarte-Bello 1997; Buck 1998; Yano and Peralta 2007; Ireland and Buck 2009.

Material examined. BRAZIL • 2 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2563, 3121 • 3 specimens; Encanto azul waterfall; 07°13′27″S, 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2723, 2731, 2758 • 5 specimens; Serrinha waterfall; 06°58′78″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2798, 2810, 2814, 2818, 2831 • 4 specimens; Dantas river; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2877, 2881, 2884, 2900 • 3 specimens; Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; G.M. Conceição leg.; HABIT 3040, 3042, 3049.

Geographic distribution. Widely distributed: AC, AM, PA, RO, RR, TO, BA, CE, MA, PB, PE, PI, DF, GO, MS, MT, ES, MG, RJ, SP, PR, RS, SC.

***Isopterygium tenerifolium* Mitt.**

Figured by Ireland 1992; Sharp et al. 1994; Buck 1998a; Oliveira e Silva and Yano 2000a; Yano and Peralta 2007; Ireland and Buck 2009.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Cancelas river; 07°04′42″S, 047°05′43″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2642 • 12 specimens; Serrinha waterfall; 06°58′07″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2795, 2799, 2800, 2801, 2815, 2816, 2824, 2827, 2838, 2847, 2850, 2866 • 5 specimens; Dantas river; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2885, 2887, 2891, 2898, 2899 • 7 specimens; Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3158, 3161, 3171, 3175, 3178, 3180, 3209.

Geographic distribution. Widely distributed: AM, PA, RO, BA, CE, DF, GO, MT, MG, RJ, SP, PR, RS, SC.

***Taxithelium planum* (Brid.) Mitt.**

Figured by Sharp et al. 1994; Florschütz-De Waard 1996; Duarte-Bello 1997; Buck 1998; Yano and Peralta 2007.

Material examined. BRAZIL • 9 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Encanto azul waterfall; 07°13′27″S, 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2685, 2705, 2725, 2728, 2729, 2736, 2754, 2768, 2771 • 12 specimens; Serrinha waterfall; 06°58′78″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2774, 2778, 2779, 2789, 2823, 2834, 2837, 2848, 2854, 2856, 2861, 2865 • 6 specimens; Dantas river; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2868, 2870, 2871, 2878, 2882, 2893 • 10 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT

2926, 2928, 2934, 2961, 2968, 2970, 2991, 3013, 3220, 3332 • 4 specimens; near to Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; F.B. Costa leg.; HABIT 3039, 3259, 3260, 3358 • 7 specimens; Cancelas river; 07°04′42″S, 047°05′43W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 3074, 3079, 3084, 3086, 3090, 3091, 3092 • 1 specimen; São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 3139.

Geographic distribution. Widely distributed: AM, PA, RO, RR, AL, BA, PE, DF, GO, MT, MG, SP.

***Taxithelium pluripunctatum* (Renauld & Cardot) W. R. Buck**

Figure 4I–K

Material examined. Brazil • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Mansinha RPPN; 07°07′08″S, 047°25′94″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3204.

This species is reported from Maranhão for the first time.

Identification. Plants medium-sized, forming lax, golden mats, stems creeping, freely branched. Stem and branch leaves slightly differentiated; stem leaves larger and longer, branch leaves more strongly papillose, falcate, lanceolate-ovate; margins subentire, serrulate at base; apex acuminate to aristate; apical cells usually smooth; costae short and double or absent; alar cells poorly differentiated in 2 rows, not inflated.

Geographic distribution. Rarely distributed: AM, RR, BA.

Sematophyllaceae Broth.

***Brittonodoxa subpinnata* (Brid.) W.R. Buck, P.E.A.S Câmara & Carv.-Silva**

Figured by Sharp et al. 1994, as *Sematophyllum*; Churchill and Linares 1995, as *Sematophyllum*; Florschütz-De Waard 1996, as *Sematophyllum*; Duarte-Bello 1997, as *Sematophyllum*; Buck 1998, as *Sematophyllum*; Yano and Peralta 2007, as *Sematophyllum*.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2571.

Geographic distribution. Moderately distributed: AC, GO, MT, ES, RJ, SP, PR, SC.

***Donnellia commutata* (Müll.Hal.) W.R. Buck**

Figure 3A–C

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3187.

This species is reported from Maranhão for the first time.

Identification. Plants are generally green, shiny, branched. Primary branches prostate, secondary branches upright, curved at the apex. Brown stem cells. Leaves non-homomalous, lax or congested, lanceolate to slightly ovate, costae absent, apex acute, margins smooth, cells smooth, rhombic, central cells vermicular, basal and marginal cells linear, inflated, colorless, apical cells quadratic or oblate.

Geographic distribution. Moderately distributed: AM, BA, DF, GO, MS, ES, MG RJ, SP.

***Microcalpe subsimplex* (Hedw.) W.R. Buck**

Figured by Sharp et al. 1994, as *Sematophyllum*; Churchill and Linares 1995, as *Sematophyllum*; Florschütz-De Waard 1996, as *Sematophyllum*; Duarte-Bello 1997, as *Sematophyllum*; Buck 1998, as *Sematophyllum*; Yano and Peralta 2007, as *Sematophyllum*.

Material examined. BRAZIL • 10 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2543, 2553, 2556, 2582, 2584, 2588, 2607, 3105, 3112, 3125 • 10 specimens; Cancelas river; 07°04′42″S, 047°05′43″W; 12 Jul. 2016; R.R. Oliveira leg.; HABIT 3058, 3059, 3066, 3067, 3069, 3073, 3076, 3078, 2641, 2644 • 5 specimens; Encanto azul waterfall; 07°13′27″S, 46°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2738, 2743, 2751, 2752 • 3 specimens; Serrinha waterfall; 06°58′07″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2776, 2805, 2845 • 3 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2902, 2962, 3412 • 14 specimens; near to Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; F.B. Costa leg.; HABIT 3035, 3043, 3053, 3055, 3344, 3345, 3347, 3350, 3353, 3354, 3355, 3357, 3359 • 15 specimens; Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3148, 3152, 3154, 3156, 3157, 3160, 3164, 3166, 3167, 3168, 3182, 3192, 3196, 3200, 3211.

Geographic distribution. Widely distributed: AC, AM, AP, BA, CE, DF, ES, GO MA, MG, MS, MT, PA, PB, PE, PI, PR, RJ, RO, RS, RR, SC, SE, SP, TO.

***Potamium lonchophyllum* (Mont.) Mitt.**

Figure 4C–E

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas; RPPN Mansinha; 07°07′08″S, 047°25′09″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2644 • 1 specimen; same locality; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3203.

This species is reported from Maranhão for the first time.

Identification. Plants forming medium-sized, dark green carpets. Leaves erect-spreading, narrowly oblong to ligulate, apex acute, costae indistinct or absent, laminar cells smooth, median cells linear, the apical shortest rhomboidal to fusiform, basal cells oblong-rectangular, rarely porous, yellow to golden, wing cells inflated, oblong or rounded-rectangular, in 2–4 rows.

Geographic distribution. Moderately distributed: AC, AM, PA, BA, DF, MT, MG.

***Trichosteleum glaziovii* (Hampe) W.R. Buck**
Figure 4L–N

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Cancelas river; 07°04′42″S, 047°05′43″W; 12 Jul. 2016; R.R. Oliveira leg.; HABIT 3087.

This species is reported from Maranhão for the first time.

Identification. Recognized by its falcate leaves, the papillae may range from large to medium to small, conspicuous or inconspicuous. Leaves falcate-lanceolate, apex serrated or entire, wing cells with a differentiated basal angle, with the presence of an inflated supra alar cell.

Geographic distribution. Moderately distributed: PE, MG, RJ, SP, PR, RS, SC.

***Trichosteleum subdemissum* (Schimp. ex Besch.) A. Jaeger**

Figured by Sharp et al. 1994; Churchill and Linares 1995; Buck 1998; Oliveira e Silva and Yano 2000.

Material examined. BRAZIL • 5 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Cancelas river; 07°04′42″S, 047°05′43″W; 19 Apr. 2016; G.M. Conceição leg.; HABIT 2560 • 2 specimens; Serrinha waterfall; 06°58′07″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2804, 2821 • 2 specimens; Dantas river; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2890, 2894. • 1 specimen; near to Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; F.B. Costa leg.; HABIT 3346 • 4 specimens; São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 3102, 3111, 3283, 3395.

Geographic distribution. Widely distributed: AM, PA, RO, RR, BA, MA, PI, DF, GO, MT, MG, RJ, SP.

***Vitalia galipensis* (Müll. Hal.) P.E.A.S. Câmara et al.**

Figured by Sharp et al. 1994; Churchill and Linares 1995; Florschütz-De Waard 1996; Duarte-Bello 1997; Buck 1998; Yano and Peralta 2007.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 3129 • 1 specimen; Encanto azul waterfall; 07°13′27″S; 46°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2749 • 1 specimen; Serrinha waterfall; 06°58′07″S, 047°22′42″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2812 • 4 specimens; Dantas river; 07°03′07″S, 047°15′28″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2872, 2873, 2876, 2888 • 2 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2992, 3234 • 2 specimens; near to Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; F.B. Costa leg.; HABIT 3018, 3036 • 4 specimens; Cancelas river; 07°04′42″S, 047°05′43″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 3062, 3065, 3080, 3088.

Geographic distribution. Widely distributed: BA, CE, DF, ES, GO, MG, MT, PA, PE, PR, RJ, RO, RR, RS, SC, SP, TO.

Stereophyllaceae W.R. Buck & Ireland

***Entodontopsis leucostega* (Brid.) Buck & Ireland**

Figured by Sharp et al. 1994; Churchill and Linares 1995; Duarte-Bello 1997, as *Stereophyllum*; Buck 1998; Gradstein et al. 2001; Yano and Peralta 2007.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, Canto da Rosa; 06°59′06″S, 047°09′09″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2739 • 1 specimen; Encanto azul waterfall; 07°13′27″S, 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2696 • 2 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 3250, 3340.

Geographic distribution. Widely distributed: AC, AM, PA, RO, RR, TO, BA, CE, MA, PB, PE, DF, GO, MT, MS, MG, RJ, SP.

***Eulacophyllum culteliforme* (Sull.) W.R. Buck & Ireland**

Figured by Sharp et al. 1994; Ireland and Buck 1994; Churchill and Linares 1995; Duarte-Bello 1997; Buck 1998a; Gradstein et al. 2001; Yano and Peralta 2007.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2631 • 1 specimen; Encanto azul waterfall; 07°13′27″S, 046°27′10″W; 20 Apr. 2016; F.B. Costa leg.; HABIT 2696 • 2 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 3250, 3340.

Geographic distribution. Widely distributed: AC, AM, AP, PA, RO, AL, BA, PB, PE, DF, GO, MT, ES, MG, RJ, SP.

***Pilosium chlorophyllum* (Hornsch.) Mull. Hall ex Broth.**

Figured by Bartram 1949; Griffin III 1979; Ireland and Buck 1994; Sharp et al. 1994; Churchill and Linares 1995; Buck 1998.

Material examined. BRAZIL • 3 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, RPPN Mansinha; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3165, 3202, 3208.

Geographic distribution. Widely distributed: AC, AM, AP, PA, RO, TO, AL, BA, PE, DF, GO, MS, MT, ES, MG, RJ, SP.

***Stereophyllum radiculosum* (Hook.) Mitt.**

Figured by Ireland and Buck 1994; Sharp et al. 1994; Costa 1994; Churchill and Linares 1995; Duarte-Bello 1997; Buck 1998; Yano and Peralta 2007.

Material examined. BRAZIL • 1 specimen; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2547 • 1 specimen; near to Cancelas; 07°04′25″S, 047°19′29″W; 12 Jul 2016; G.M. Conceição leg.; HABIT 3044.

Geographic distribution. Widely distributed: PA, BA, GO, MT, MS, ES, MG, RJ, SP, PR, SC.

Thuidiaceae Schimp.

***Pelekium schistocalyx* (Müll.Hal.) Touw**

Figured by Crum and Anderson 1981, as *Thuidium*; Sharp et al. 1994, as *Cyrto-hypnum*; Duarte-Bello 1997, as *Thuidium*; Buck 1998, as *Cyrto-hypnum*; Yano and Peralta 2007, as *Cyrto-hypnum*.

Material examined. BRAZIL • 12 specimens; Maranhão, Carolina, Parque Nacional da Chapada das Mesas, São Romão waterfall; 07°01′28″S, 047°02′45″W; 19 Apr. 2016; R.R. Oliveira leg.; HABIT 2529, 2539, 2544, 2552, 2557, 2561, 2576, 2577, 2583, 2609, 2627, 2634 • 16 specimens; Prata waterfall; 06°59′06″S, 047°09′09″W; 11 Jul. 2016; R.R. Oliveira leg.; HABIT 2656, 2908, 2911, 2917, 2922, 2973, 2975, 2997, 3008, 3243, 3245, 3304, 3306, 3318, 3329, 3334 • 3 specimens; Mansinha RPPN; 07°07′08″S, 047°25′09″W; 13 Jul. 2016; R.R. Oliveira leg.; HABIT 3159, 3184, 3188.

Geographic distribution. Widely distributed: AC, AM, PA, RO, RR, MA, PE, DF, GO, MS, MG, RJ, SP, PR, RS, SC.

Discussion

Our data reinforce the importance of creating and maintaining protected area in the Cerrado, as it is the second largest phytogeographic domain in South America and considered one of the world's biodiversity hotspots, as determined by the great number endemic and threatened plant species (Myers et al. 2000). The Cerrado is increasingly undergoing anthropic threats (Primack and Rodrigues 2001).

We found 26 species in the PNCM, which is in the Cerrado domain. This is greater than the number of species found by Câmara (2008), who cataloged 17 species of pleurocarpous mosses in gallery forest areas of the Cerrado. Our results are also more representative than the results by Conceição et. al. (2010), who recorded 11 species. Thus, we significantly add to the knowledge of pleurocarpous mosses in Maranhão. Amoung the species of pleurocarpous mosses found, 12 species (24%) are reported from Maranhão for the first time. Cladocarpous mosses represent only 7% of the bryoflora of the PNCM.

In addition to being are recorded for the first time from Maranhão, *Herpetineuron toccoae*, *Entodon hampeanus*, and *Trachyphyllum dusenii* are also reported here for the first time from the northeast region of Brazil. The species report here for the first time from the state or region represent 11% of the bryophyte flora in the PNCM. Amoung the species of cladocarpous mosses, *Groutiella tomentosa* is recorded for the first time from Maranhão. In the Northeast Region, this species is known to occur in the Bahia, Sergipe, Ceará, and Pernambuco (Flora of Brasil 2020).

The results of our survey in the PNCM add important information on the diversity, occurrence, and the geographic distribution of bryophyte species in this protected area, the Northeast Region, and the Cerrado. *Trachyphyllum dusenii* (Pterigynandraceae) is recorded for the first time from the Northeast Region. *Isopterygium subbrevisetum*, *Taxithelium pluripunctatum*, and *Trichosteleum glaziovii* are recorded for the first time from the Cerrado as well as from Maranhão. Finding these species shows the importance of the PNCM, and the ecotone that it protects, for maintaining the biodiversity of bryophytes.

The most frequently found species in our study was *Microcalpe subsimplex* (71 specimens), followed by *Vesicularia vesicularis* (61 specimens) and *Chrysohypnum diminutivum* (43 specimens). Eighteen of the 28 species of pleurocarpous mosses have a wide distribution in Brazil and represent 64% of the local bryoflora . Species such as *Taxithelium planum*, *Trichosteleum subdemissum*, *Isopterygium tenerum*, *I. tenerifolium*, and *Pelekium schistocalyx* are generalists and readily occupy various types of substrates the can establish populations in restrictive environmental conditions, such as disturbed, sandy soils and artificial substrates (Gradstein et al. 2001); thus, these species are frequently found in floristic surveys. Seven species that we found have a moderate distribution (25%), while three species have a rare distribution (11%). The occurrence of rare species and a species-rich bryoflora reinforce the need for more studies in the PNCM, as well as for greater conservation efforts in the park.

We found the rupicolous mosses most predominant in the PNCM, representing 88% of all species collected, followed by corticicolous (7%), epixilous (3%), and terricolous (2%) mosses. There is ample availability of rock surfaces for rupicolous species in our study area. Correia et al. (2015) also reported a prevalence of rupicolous species in their study. In our study, 26% of the species were exclusive to one type of substrate (i.e. mono-substrate), while 64% colonized two or three different types of substrate (i.e. poly-substrate).

Our study is the first such study of the pleurocarpous and cladocarpous mosses in the PNCM region. Our results provide important information on the bryoflora in the Northeast Region of Brazil. We emphasize here that floristic studies are important to better understand biodiversity and help towards the conservation of habitats and species, especially those with restricted distributions; additionally, floristic studies are also essential for the management of protected areas.

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Authors' Contributions

RRO collected the data, wrote the text, and identified the specimens; RFO and GMC reviewed the text; HCO and DFP confirmed the identifications and reviewed the text.

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